Induced mitochondrial membrane potential for modeling solitonic conduction of electrotonic signals

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Supporting information

S2 Appendix: Local Stability Analysis

The equilibrium solution of Eq (15) (in the manuscript) with boundary conditions $U_0(\pm\infty)$=0 is $U_0 = \alpha\kappa V_0$, where $V_o = \frac{a}{b}\text{sech}^2\left[(a\lambda^2 g_a^* r_i)^{\frac{1}{2}}\frac{X}{2}\right]$ [1] and $\lambda = \sqrt{\frac{r_m}{r_i}}$. Linearization of Eq (15) (in the manuscript) yields the linearized version of the nonlinear cable equation:

$$(1+\eta-\delta U_0)U + (1-2U_0)\frac{\partial U}{\partial T} = \frac{\partial^2 U}{\partial X^2} + \gamma\frac{\partial^3 U}{\partial T \partial X^2} \tag{1}$$

Consider the solution of this equation to be written in this form:

$$U(X,T) = \exp(\theta T + ikX) \tag{2}$$

where θ is the eigenvalue of the wave, k is the wave number. Eq (2) is substituted into Eq(1) in order to obtain the dispersion relation:

$$\theta = -\left(\frac{1+\eta-\delta U_0+k^2}{1-2U_0+\gamma k^2}\right) \tag{3}$$

For local stability $\theta < 0$ and for this dispersion relation given by Eq (3), the equilibrium solution is therefore shown to be locally stable for all $\eta > 0$ and $\gamma > 0$ if the following condition is satisfied:

$$2(1+\eta) < \delta < \frac{2}{\gamma} \tag{4}$$

i.e., the equilibrium potential is

$$V_a = \frac{\eta}{\delta} < 0.5 - \frac{1}{\delta} \tag{5}$$

References

1. Cacha LA, Ali J, Rizvi ZH, Yupapin P, Poznanski RR. Nonsynaptic plasticity model of long-term memory engrams. Journal of Integrative Neuroscience. 2017;16(4):493–509.